Seasonality of a fish assemblage in shallow waters of Duće-Glava, eastern middle Adriatic

by

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ABSTRACT. - A shallow-water fish assemblage associated with macroalgae, rocks and seagrasses with a sandy substratum at Duće-Glava beach, eastern middle Adriatic, was sampled monthly with a beach seine. Sampling was at 4-h intervals over 24 h each month between April 2000 and March 2001. A total of 61 species were recorded; the assemblage was dominated by five species: *Pomatochistus marmoratus, Lithognathus mormyrus, Sardina pilchardus, Atherina boyeri* and *Atherina hepsetus*. The number of fish caught per season was highest in spring and lowest in winter, and the biomass followed a similar trend with a greater decline between spring and summer. There was significant seasonal difference in the species assemblage. Species diversity (H') and evenness (J') were highest between April and July, decreased in August, and remained low until March. Twenty-seven species were residents in soft-sediment areas, while others are seasonal transients and probably use the area as a shelter or nursery ground.

RÉSUMÉ. - Modifications saisonnières dans une communauté de poissons des eaux peu profondes de Duće-Glava, Adriatique moyenne orientale.

Une communauté de poissons des roches couvertes de macroalgues et des herbiers dans une eau peu profonde, associée à un substrat sableux de la plage de Duće-Glava, Adriatique moyenne orientale, a été échantillonnée chaque mois à l'aide d'une petite seine de plage. Le prélèvement a été effectué à intervalles de 4 h sur 24 une fois par mois, d'avril 2000 à mars 2001. Au total, 61 espèces ont été capturées et la communauté était dominée par cinq espèces: *Pomatochistus marmoratus, Lithognathus mormyrus, Sardina pilchardus, Atherina boyeri* et *A. hepsetus*. Le nombre d'individus capturés par saison a été le plus grand au printemps et le plus petit en hiver. Les variations saisonnières de la biomasse ont suivi la même tendance, bien que la diminution entre printemps et été ait été beaucoup plus importante. Une différence significative dans la communauté des espèces a été observée entre les différents mois et les saisons. La diversité des espèces (H') et leur présence (J') ont été les plus élevées entre avril et juillet, ont diminué en août, et sont restées basses jusqu'en mars. Vingt-sept espèces peuvent être considérées comme résidentes dans les secteurs de sédiment meuble, alors que les autres sont des espèces en transit utilisant probablement le secteur d'étude comme abri de nurserie.

Key words. - Fish assemblage - MED - Eastern Adriatic Sea - Shallow water - Inshore Mediterranean - Seasonal changes.

Numerous studies have focused on seasonality in shallow-water fish assemblages on soft sediments (Lasiak, 1984; Nash, 1988; Wright, 1988; Ali and Hussain, 1990; Santos and Nash, 1995). These studies vary from descriptions of fish assemblages and their dynamics to an examination of the effects of severe seasonal changes in environmental conditions (Nash, 1988; Santos and Nash, 1995).

Most of the few studies on fish assemblages in soft-bottom areas in the eastern Adriatic (Kraljević and Jug-Dujaković, 1987; Jug-Dujaković, 1988; Dulčić *et al.*, 1997; Matić *et al.*, 2001) were only preliminary investigations. There is considerable variability in the potential density of fish in shallow water areas (Ross *et al.*, 1987). It is interesting to examine the state of the shallow-water habitat in the Eastern Adriatic with respect to other areas.

This study provides: 1) a description of temporal fluctuations in a shallow-water, soft-sediment fish assemblage in an estuarine area with mixed habitats, and 2) a comparison with other subtropical and temperate studies. This study establishes a baseline to compare with future monitoring programs to follow change due to antropogenic influences on the area.

MATERIAL AND METHODS

Duće-Glava (43º26'30"N; 16º41'E) is a small south-facing sandy beach in the middle Adriatic near the Cetina estuary, its western coast is 6 km long, shallow and sandy (Fig. 1). The sampling area (350 m between two small piers) was sandy with stones and pebbles with a seaweed canopy of *Cystoseira barbata* and *Ulva rigida,* and partially overgrown with seagrass *Posidonia oceanica*.

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Samples were collected monthly over 11 months (April 2000-March 2001). No sampling was done in January 2001 due to exceptionally bad conditions. Each month, 7 sub- samples were taken at 4-hour intervals. Sampling was using a 22 m beach seine with 7.5 m wide wings and central collecting area of 7 m (4 mm stretch mesh at the wings reducing to 2 mm in the centre), at depths between 0.1 and 1.5 m. Before each sample, water temperature was measured and salinity was recorded with a laboratory inductive salinometre.

Fish were immediately preserved and identified using Jardas (1996). Total lengths (to the nearest 0.1 mm) and weights (to the nearest 0.01 g) were measured for each individual. Juvenile fishes were defined as sexually immature with scales already formed (Katavić, 1984).

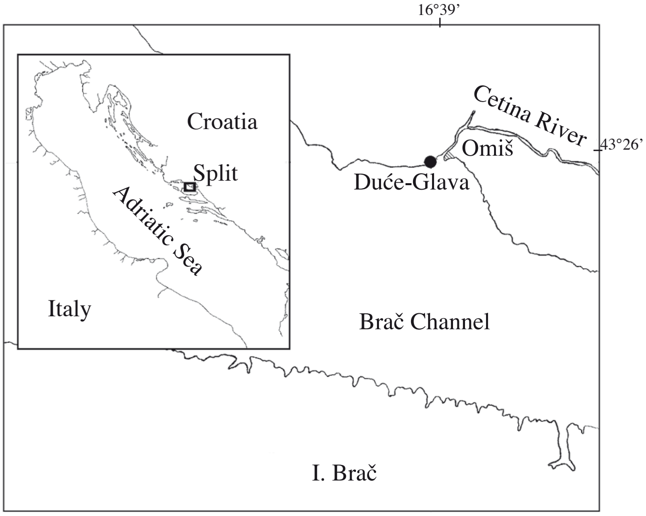

Figure 1. - Map showing the area of Duće-Glava Bay and the Cetina Estuary. *[Carte de la région de la baie de Duće-Glava et de l’estuaire Cetina.]*

The fish data were analyzed using the PRIMER software package (Plymouth Marine Laboratories, UK; Clarke and Warwick, 2001). Data were transformed for presence/ absence and the Bray-Curtis similarity matrix was used to generate 2-dimensional ordination plots with the non-metric multidimensional scaling (nMDS) technique (Clarke, 1993). ANOSIM2 test for the un-replicated 2-way layout was used for testing differences in species assemblage between seasons and sites (Clarke and Warwick, 2001). Probability value was set at 0.05.

Temporal variations in community structure, abiotic factors and interactions between these variables were analysed using multiple linear regression. Correlations were calculated with STATISTICA. Species diversity was the number of species and the Shannon diversity index (H’). The equitability among species was measured with Piélou’s (1977) evenness function (J).

RESULTS

Mean daily temperature over the year (2000-2001) ranged from 12.3°C in February 2001 to 23.0°C in July 2000, while salinity ranged from 27.7 psu in February 2001 to 35.3 psu in July 2000.

The annual total catch consisted of 17,414 fish representing 61 species (Tab. I). Juveniles represented most fish species. The mean number of species collected ranged from 20 in November to 47 in August (Fig. 2A). Diversity was highest in late spring and summer, although there was a large fluctuation in the number of species between those months. The total biomass collected was 30,215.72 g. The mean monthly biomass ranged from 1,442.63 g in March to 6,894.7 g in May. It increased from April to June, then steadily declined until February and

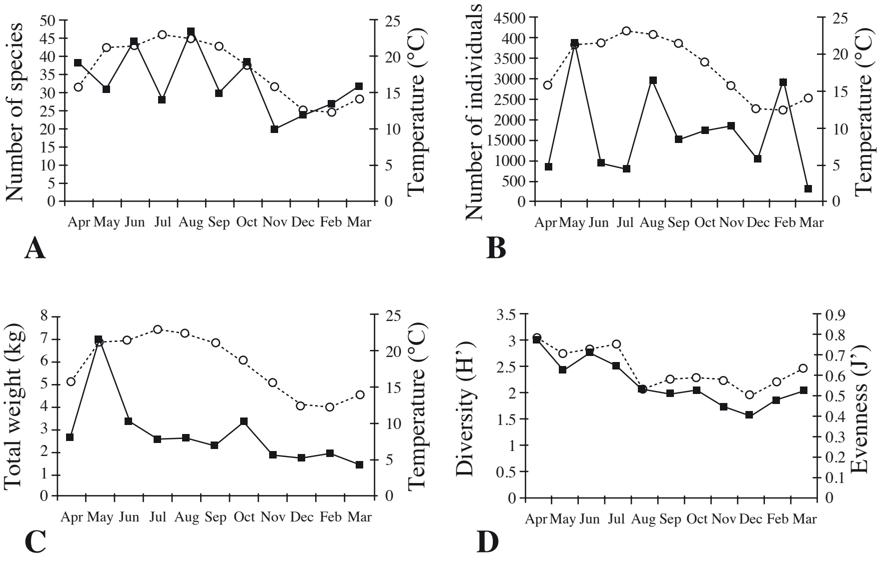

Figure 2. - Seasonal variation in the shallow water fish assemblage at Duće-Glava Bay between April 2000 and March 2001. **A**: Number of fish species (■, solid line) and temperature (○, dashed line). **B**: Number of individuals (■, solid line) and temperature (○, dashed line). **C**: Biomass (■, solid line) and temperature (○, dashed line). **D**: Species diversity (H) (■, solid line) and evenness (J) (○, dashed line). *[Variations saisonnières de la communauté de poissons de roche dans la baie de Duće-Glava entre avril 2000 et mars 2001.* ***A*** *: Nombre d’espèces de poissons (■, ligne continue) et température (○, ligne pointillée).* ***B*** *: Nombre d’individus (■, ligne continue) et température (○, ligne pointillée).* ***C*** *: Biomasse (■, ligne continue) et température (○, ligne pointillée).* ***D*** *: Diversité des espèces (H) (■, ligne continue) et présence (J) (○, ligne pointillée).]*

rise slightly in March (Fig. 2B). The mean number of fish ranged from 302 in March to 3,868 in May (Fig. 2C). Number of individuals caught per season was highest in spring (5,624), declined slightly in summer and autumn, and was lowest in winter (1,520). The seasonal change in biomass followed a similar trend to number of individuals, although the decline between spring and summer was much greater than for the number of individuals. Species diversity (H') and evenness (J') were highest between April and July, decreased in August, and remained low until March (Fig. 2D). H' values fluctuated from 1.56 in December to 3.03 in April, while J' ranged from 0.51 in December to 0.79 in April. Despite a high number of species caught in June and August, the diversity index for those months was not higher because only a few individuals from certain species were generally present and therefore contributed little to the overall diversity.

The nMDS plots of fish assemblages (Fig. 3) shows there is a difference between fish assemblages in all months, especially March, except in late autumn and winter. The greatest differences were between spring and autumn-winter months. The fish assemblage varied little during winter.

Results of ANOSIM2 test for the un-replicated 2-way layout showed that there was significant difference in species assemblages among months ($\rho_{av} = 0.438$, $p = 0.001$), and between seasons ($\rho_{av} = 0.431$, $p = 0.019$).

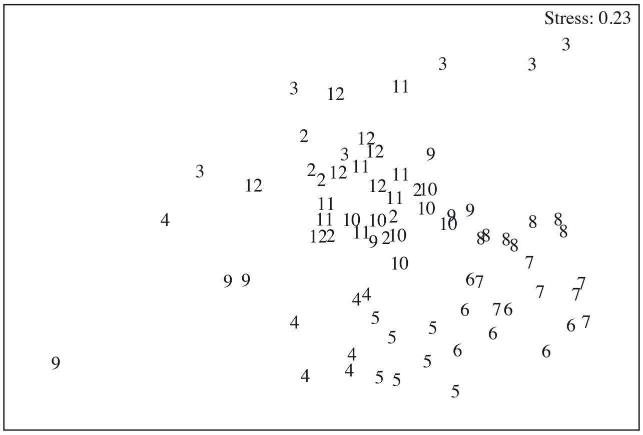

Figure 3. - Non-Metric Multidimensional Scaling ordination plot for each month (stress < 0.23): (2) February; (3) March; (4) April; (5) May; (6) Juny; (7) July; (8) August; (9) September; (10) October; (11) November; (12) December. *[Tracé d'ordination par la méthode de cadrage multidimensionnel non-métrique (stress < 0,23) : (2) Février ; (3) Mars ; (4) Avril ; (5) Mai ; (6) Juin ; (7) Juillet ; (8) Août ; (9) Septembre ; (10) Octobre ; (11) Novembre ; (12) Décembre.]*

The dominant species by number were: *Pomatochistus*

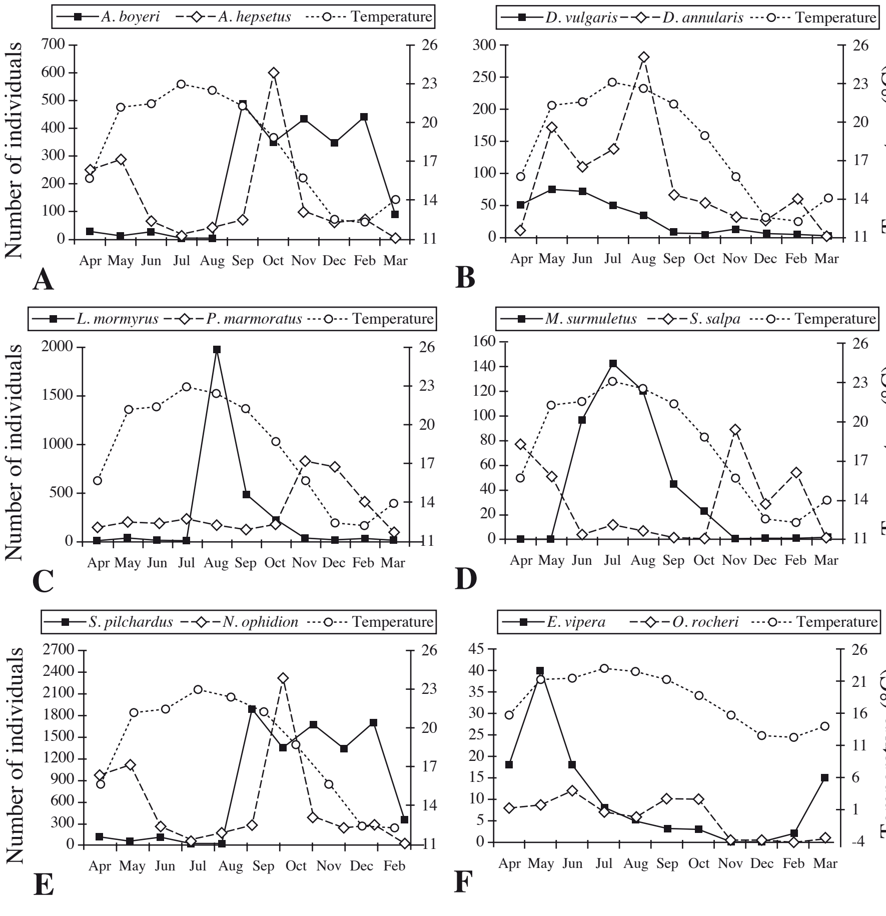

Figure 4. - Seasonal variations in the abundance (number of individuals) (■, solid line or ◇, dashed line) and temperature (○, dashed line) of dominant or rare fish species at Duće-Glava Bay between April 2000 and March 2001. **A**: *Atherina boyeri* and *A. hepsetus*. **B**: *Diplodus vulgaris* and *D. annularis*. **C**: *Lithognathus mormyrus* and *Pomatoschistus marmoratus*. **D**: *Mullus surmuletus* and *Sarpa salpa*. **E**: *Sardina pilchardus* and *Nerophis ophidion*. **F**: *Echiichthys vipera* and *Ophidion rochei*. *[Variations saisonnières de l'abondance (nombre d'individus) (■, ligne continue ou ◇, ligne pointillée) et température (○, ligne pointillée) des espèces de poissons dominantes ou rares dans la baie de Duće-Glava entre avril 2000 et mars 2001.]*

Table I. - Total number of individuals and biomass of fish caught with a beach seine at Duće-Glava Bay between April 2000 and March 2001 (no samples in January 2001), ordered by importance in % of total weight. *: Denotes species collected but not weighed. *[Nombre total d'individus et biomasse des poissons capturés à la senne de plage dans la baie de Duće-Glava entre avril 2000 et mars 2001 (pas d'échantillon en janvier 2001), rangés par ordre croissant en % du poids total. * : Espèces collectées, mais non pesées.]*

Species	Total number	Number (%)	Total weight (g)	Weight (%)	Species	Total number	Number (%)	Total weight (g)	Weight (%)
Sardina pilchardus	2,775	15.94	3,474.58	11.50	*Diplodus puntazzo*	148	0.85	83.31	0.28
Atherina boyeri	2,204	12.66	3,365.01	11.14	*Liza saliens*	1	0.01	80.62	0.27
Atherina hepsetus	1 565	8.99	3,278.23	10.85	*Callionymus pusillus*	60	0.34	66.76	0.22
Diplodus annularis	967	5.55	2,956.05	9.78	*Knipowitschia panizzae*	41	0.24	64.46	0.21
Mullus surmuletus	428	2.46	2,440.74	8.08	*Solea kleini*	17	0.10	51.25	0.17
Diplodus vulgaris	318	1.83	1,547.13	5.12	*Trigla lucerna*	4	0.02	47.49	0.16
Pomatoschistus marmoratus	3,395	19.50	1,460.27	4.83	*Syngnathus acus*	66	0.38	44.89	0.15
Ophidion rochei	63	0.36	1,344.02	4.45	*Liza ramada*	18	0.10	36.33	0.12
Liza aurata	138	0.79	1,147.77	3.80	*Diplodus sargus*	3	0.02	30.80	0.10
Lithognathus mormyrus	2,875	16.51	933.19	3.09	*Trachinus draco*	3	0.02	30.03	0.10
Parablennius sanguinolentus	64	0.37	911.67	3.02	*Parablennius incognitus*	8	0.05	28.18	0.09
Echiichthys vipera	112	0.64	815.42	2.70	*Pagellus erythrinus*	1	0.01	23.18	0.08
Symphodus ocellatus	182	1.05	681.87	2.26	*Parablennius tentacularis*	3	0.02	15.06	0.05
Sarpa salpa	327	1.88	635.72	2.10	*Nerophis maculatus*	35	0.20	13.29	0.04
Symphodus cinereus	63	0.36	573.18	1.90	*Ledidotrigla cavillone*	5	0.03	11.33	0.04
Gobius geniporus	155	0.89	428.91	1.42	*Symphodus rostratus*	3	0.02	9.19	0.03
Chelon labrosus	88	0.51	366.23	1.21	*Arnoglossus thori*	3	0.02	8.48	0.03
Anguilla anguilla	2	0.01	336.13	1.11	Gobiid	2	0.01	7.03	
Gobius cobitis	56	0.32	325.72	1.08	*Salmo trutta trutta*	1	0.01	6.90	
Mugil cephalus	13	0.07	283.27	0.94	*Syngnathus abaster*	9	0.05	6.65	
Arnoglossus laterna	114	0.65	270.77	0.90	*Zebrus zebrus*	12	0.07	6.25	
Nerophis ophidion	661	3.80	259.54	0.86	*Lipophrys pavo*	1	0.01	5.09	
Scorpaena porcus	11	0.06	243.28	0.81	*Sciaena umbra*	1	0.01	5.03	
Syngnathus typhle	100	0.57	212.58	0.70	*Labrus merula*	1	0.01	4.04	
Symphodus roissali	27	0.16	210.10	0.70	*Callionymus maculatus*	1	0.01	1.27	
Gobius niger	43	0.25	210.02	0.70	*Lipophrys trigloides*	1	0.01	1.23	
Labrus viridis	4	0.02	173.62	0.57	*Sparus aurata*	4	0.02	0.34	
Zosterisessor ophiocephalus	5	0.03	157.61	0.52	*Eutriglia gurnardus*	1	0.01	*	
Lichia amia	9	0.05	149.59	0.50	*Hippocampus ramulosus*	1	0.01	*	
Belone belone	9	0.05	129.29	0.43	Total number of species	61			
Pomatoschistus canestrinii	72	0.41	120.72	0.40	Total number of individuals and total weight (g)	17,414		30,215.72	
Callionymus risso	115	0.66	85.01	0.28					

marmoratus (19.5% of individuals), *Lithognathus mormyrus* (16.5%), *Sardina pilchardus* (15.9%), *Atherina boyeri* (12.7%) and *Atherina hepsetus* (9.0%). Each of these species had a different pattern of seasonal abundance. *S. pilchardus* were only caught in May (Fig. 4). The greatest abundance of *P. marmoratus* occurred from November to February, while *A. boyeri* was abundant from September to February. The highest abundance of *A. hepsetus* occurred from April to June and then in October. The summer rise in abundance of *L. mormyrus, D. annularis, D. vulgaris* and *M. surmuletus* was due to age 0^+ and 1^+ fish. The dominant species by biomass were *S. pilchardus* (20.0%), *A. boyeri* (11.1%), *A. hepsetus* (10.8%), *D. annularis* (9.8%) and *Mullus surmuletus* (8.1%) (Fig. 4). Almost all individuals of *Ophidion rochei* occurred during April to October and during the night. Among the 61 species caught, 27 were considered residents of soft-sediment areas, while the remaining 34 species were transients, which probably use the area as shelter and a nursery ground.

There was no significant correlation between mean monthly temperature and any community parameter (biomass, number of species, number of individuals, diversity, evenness, 9 d.f. $p > 0.05$). The results indicated that variations in abiotic factors could predict more than 70% of the monthly variations in species number mainly because of the interaction effect of temperature and salinity. The variation in number of individuals showed no significant correlation with the independent variables. Results also suggest that temperature could predict about 63% of the variability associated with monthly fluctuations in diversity.

Abundance of several dominant or rare species was correlated with temperature. Based on the multiple linear regression models it was found that six species were positively correlated with temperature: *O. rochei* (0.78, $R^2 = 0.64$), *M. surmuletus* (0.77, $R^2 = 0.48$), *L. mormyrus* (0.43, $R^2 = 0.45$), *D. annularis* (0.72, $R^2 = 0.55$), *Symphodus ocellatus* (0.70, $R^2 = 0.48$) and *Diplodus vulgaris* (0.60, $R^2 = 0.55$). *E. vipera* (0.30), *A. hepsetus* (0.07) and *S. pilchardus* (0.27) were weakly positively correlated with temperature. No species was strongly negatively correlated with temperature, but four species were weakly negatively correlated with temperature: *Nerophis ophidion* (-0.54, $R^2 = 0.22$), *P. marmoratus* (-0.52, $R^2 = 0.22$), *Sarpa salpa* (-0.48, $R^2 = 0.19$), and *A. boyeri* (-0.46, $R^2 = 0.18$). Only two species, *Liza aurata* (-0.55, $R^2 = 0.40$) and *Diplodus vulgaris* (-0.48, $R^2 = 0.44$) were negatively correlated with salinity.

DISCUSSION

The five numerically dominant species in this study (*Pomatoschistus marmoratus, Lithognathus mormyrus, Sardina pilchardus, Atherina boyeri* and *A. hepsetus*) are at a low trophic level with a high ecological efficiency (Dulčić *et al*., 1997). In the Gulf of Olbia (NE Sardinia, Italy), planktivorous species (atherinids) numerically dominated the fish community, followed by epi-benthic fish, chiefly labrids and sparids (Guidetti and Bussotti, 2000). At Duće-Glava, the predominance of juvenile fish confirms this site is a nursery area. It is also possible that sampling design (our choice in number of surveys, specific locations, type of net) could partially influence the results, especially because of relevant replications in space. However, the predominance of juvenile specimens could also be the result of the use of the small beach seine lessening our ability to catch larger and more elusive individuals in greater numbers. It is important to consider the selectivity of nets to catch species of different sizes or forms and the behaviour of fish in front of the beach seine. The external factors as light, sound, net velocity, fish velocity, and sense organs (lateral line, eyes, ears) also influence this escape behaviour (Foster, 1969). The nursery function of estuaries and inshore waters is well known (Blaber and Blaber, 1980; Robertson and Duke, 1987; Santos and Nash, 1995). Shallow coastal areas are important for many demersal fishes because many of them have complex life cycles that begin with a pelagic larval stage in open waters, followed by demersal stages in coastal habitats. Estuaries, coastal lagoons and protected bays are important to fisheries because they are productive and required in the life cycles of many marine fishes (Rodriguez *et al*., 1998). Many biotic and abiotic factors play an important role in determining survivorship during the early life stages of demersal fishes.

The Adriatic Sea is generally oligotrophic (Zore-Armanda *et al*., 1987). It contains 420 fish species and subspecies (Dulčić and Grbec, 2000). In this study, 61 fish species were recorded representing 14.5% of Adriatic Sea ichthyofauna. Dulčić *et al*. (1997) found 69 fishes occupying small coves of Kornati Islands (middle Adriatic), while Matić *et al*. (2001) found 38 species in the coves along the western coast of peninsula Istra (Northern Adriatic). This study at Duće-Glava cannot be directly compared with studies in other shallow-water areas over the world because of different sampling methods. However, other studies have found 23 species in the Gulf of Olbia, NE Sardinia, Italy (Guidetti and Bussotti, 2000), 47 species in the Gulf of Fos, France (Letourneur *et al*., 2001), 37 species in Kuwait Bay, Kuwait (Wright, 1988), 32 species in Newport Bay, California (Allen, 1982), 50 species in Kings Bay, South Africa (Lasiak, 1984), 55 species in Bahia Concepcion, Mexico (Rodriguez *et al*., 1998), 22 (site Hvervenbukta) and 33 species (site Ellingstad) in Oslofjord, Norway (Nash, 1988), 46 species in Botany Bay, Australia (Bell *et al*., 1984) and 24 species in Porto Pim, Faial, Azores (Santos and Nash, 1995).

Fish assemblage at Duće-Glava was diverse ($1.56 < H' > 3.03$) and evenness ($0.51 < J' > 0.79$). This range of values reflects the use of different habitats by various species. Species diversity is similar to similar areas, e.g., H' 0.03-1.11, J' 0.01-057 for Colorado Lagoon, California (Allen and Horn, 1975), Iriven Bay, Scotland H' 1.17-1.97, J' 0.57-0.77 (Nash and Gibson, 1982), Cabrillo beach area, Los Angeles H' 0.50-2.50 (Allen *et al*., 1983), Kohr-al-Zubair, Arabian Gulf H' 1.19-2.36, J' 0.57-0.80 (Ali and Hussain, 1990), and Kornati archipelago, Adriatic H' 1.12-2.70, J' 0.32-0.77 (Dulčić *et al*., 1997).

At Duće Glava, the 27 resident species varied in abundance, biomass, and distribution. Most of these abundant and dominant fish were small species that tolerate wide temperature fluctuations, have daytime habits, are third-order consumers, have preference for soft-bottom habitats, have limited displacement capacity.

The fish assemblage in Duće-Glava is relatively undisturbed. The area provides shallow-water macroalgal rocks and seagrasses habitat close to the river Cetina estuary. The only major disruptions are large numbers of bathers during daylight through the summer, occasional fishing on juvenile pelagic fish and fishing by trawl in Brač channel. The fish assemblage undergoes a strong seasonal change in abundance. This is typical of shallow-water fish assemblages (Lasiak, 1984; Ross *et al*., 1987; Nash, 1988; Wright, 1988; Santos and Nash, 1995; Rodriguez-Romero *et al*., 1998) with low abundances in the winter. Species diversity was greatest in August when temperatures were around median and the early juveniles of many species become demersal. Many common eastern Adriatic fish spawn during spring and summer (Jardas, 1996). Recruitment of these species may explain the high abundance during August. Ecological separation of the dominant species is achieved by difference in the timing of settlement and recruitment (Tzeng and Wang, 1992). Environmental variables were also correlated with the number and abundance of fish species in the Tanshui River estuary (Tzeng and Wang, 1992). Dulčić *et al*. (1997) observed similar segregation in some families (Harmelin-Vivien *et al*., 1995). The correlation between biotic factors and seawater temperature does not necessarily imply a causal relationship. Water temperature is a factor influencing fish distribution (Allen and Horn, 1975; Ali and Hussain, 1990; Tzeng and Wang, 1992; Guidetti and Bussotti, 2000). In temperate seas such as the Adriatic, most species have seasonal biological cycles and spawn or settle at a particular period of the year (Dulčić *et al*., 1997). The abundance of six species in this study were positively correlated with temperature, *Ophidion rochei, Mullus surmuletus, Diplodus annularis, Lithognathus mormyrus, Symphodus ocellatus* and *Diplodus vulgaris*; while four were negatively correlated, *Nerophis ophidion, Pomatoschistus marmoratus, Sarpa salpa* and *Atherina boyeri*. Guidetti and Bussotti (2000) found almost similar results for the Gulf of Olbia-positively correlated with temperature were: *Symphodus cinereus, Symphodus tinca, Diplodus annularis* and *Mullus surmuletus*, while negatively correlated were: atherinids, *Coris julis* and *Sarpa salpa*. Only two species (*Liza aurata* and *D. vulgaris*) were negatively correlated with salinity in this study. Guidetti and Bussotti (2000) found *D. vulgaris, S. salpa* and *Gobius bucchichii* negatively correlated with salinity for the Gulf of Olbia, Sardinia. Salinity may influence fish community structure and distribution in shallow estuarine seagrass habitats (Ter Morshuizen and Whitfield, 1994). However, there was no relationship between fish density and salinity in South African *Zostera capensis* systems (Ter Morshuizen and Whitfield, 1994). Bottom and Jones (1992) suggest that the distribution of fish assemblages is strongly influenced by fresh-water inflows in some North American estuaries.

The substrate type (Levin, 1991) and depth (Garcia-Rubies and Macpherson, 1995) are two of the main factors affecting fish recruitment, mortality and growth (Macpherson, 1994). Letourneur *et al*. (2003) found that bottom slope was generally more significant than depth. Furthermore, Letourneur *et al*. (2003) suggested that benthic habitat used by fish is clearly non-random, and that differences in habitat at a small spatial scale affect fish assemblages.

At Duće-Glava the major changes in the species compositions occurred during the spring and summer when there were influx of *A. hepsetus*. The large change in May was due to the influx of juvenile *S. pilchardus*, which spawns from October to April (Jardas, 1996).

The results of the present study provide a basis for establishing the temporal and spatial patterns of recruitment in various fish species. Following this study, we recommend long-term research to establish whether the correlation between biotic factors and temperature really exists.

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